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PROBLEMS OF EPIDEMIOLOGICAL EVALUATION OF WATER CONTENTS

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(Probleme der epidemiologischen Beurteilung von Wasserinhaltstoffen)

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In the newest edition of a large dictionary /1/, the word "epidemiology" has the following definition:

"Epidemiology - Greek - study of infectious diseases, study of epidemics and the study of their conformity to natural law. In English usage, the concept also has recently been widened to the statistical description of non-infectious diseases."

The word "recently" is disturbing in this definition, since etymological study /2/ gives the Greek adjective "epidemios" = spread throughout the people, and the noun "epidemia noson," disease of the people, as the root of the word "epidemic." Epidemiology is also the study of those diseases which spread locally and temporarily in a population. Due to these characteristics, they are in contrast to other diseases, and not due to the fact that their cause is infectious or non-infectious. First the discovery of infectious viruses led to a narrowing down of the concept "epidemiology," the preferred definition of which had been the study of the causes, spread, battle against and prevention of epidemics and other contagious diseases.

In a technicalized and highly civilized country, the epidemics of the previous century have lost their preeminence, while - often as a result of technology and civilization - non-contagious diseases come to the fore, which are called

"national diseases" due to their increasing spread. Analogous to infectious diseases, which become an epidemic through increased distribution, epidemiological analysis of non-contagious mass diseases deals with local and temporarily defined quantitative characteristics. Moreover, a correlation between the disease and the climate, race, age, sex, eating habits, way of life, social position, living conditions or profession, must necessarily ensue. Therefore, in contrast to the infectious disease, which has a fixed cause, in the form of a specific virus, there can only be environmental factors which cause the appearance of non-communicable, widespread diseases. But associated therewith is the fact that the cause of these diseases very frequently can only be ascertained on the basis of hypothetical deduction.

Since ancient times it has been known that drinking water can play a role as a determining factor for the widespread appearance of diseases. In the opinion of Hippocrates /3/, disease is a reaction process between the human organism and air, water and local environment. Therefore, he writes in the foreword of his book "Peri aeron, hydation, topon": "Whoever wishes to engage in the art of medicine ... must also consider the effect of the waters, since as they are distinguishable in regard to taste and heaviness, so also is the effect of individual waters different .... Furthermore, one must take into account whether the water is marshy, soft or hard, comes from the sky or the mountains, or also salty

and not to be softened .... If man wants to be healthy, it depends mostly on the water. Marshy, standing water and water from ponds is ... warm, thick, and odorous .... That which flows from mountains, where ... iron, copper, silver, gold, sulphur, alum, mineral pitch and natron appear, causes urine problems and constipation. The best water comes from high lying regions. Then it is sweet and has a thin flowing consistency ...."

Based on the properties of water, Hippocrates established by observation alone a drinking water/human disease correlation which we can characterize today as aesthetic and organoleptic. Later this could be improved upon, where with the appearance of a drinking water epidemic, the virus or the morbific agent in non-infectious diseases connected with drinking water was known. To the necessarily quantitative criterion just shown for the characterization of a mass disease, a qualitative one has been added, namely knowledge of the cause. That does not exclude the fact that with diseases associated with drinking water, the qualitative criterion in the form of the cause can again have a quantitative character; because it is known that too little water leads very quickly to death, as much as a large consumption of water can cause health problems, such as the water disease of those who work with heat, which leads to chronic gastritis with long-term diarrhea.

These diseases, which are only determined by the amount of water, move into the background compared to all those

diseases associated with drinking water which are induced by a qualitative feature, namely either poisonous substances in the drinking water or by too little or too much of one or more physiological substances in the water, such as natrium, calcium or chloride.

In the evaluation of these water contents for public health, difficulties already arise when it must be decided whether they are necessary or whether drinking water requirements can be met over a long period of time with rain water or desalinated sea water or by distillation. If a decision on the effects of using salt-free water over a long period is difficult at the moment, by way of contrast there is already statistical proof on the use of water with a high salt content: in the USA, as a result of lengthy use of drinking water rich in salt, hypertension was detected in infants /4/. Russian studies have shown that in 12.4% of the adult population of a locality, which had drinking water with over 600 mg/l chlorides bound as NaCl, blood pressure was over 160/95 mm Hg, while in another locality with drinking water with low chloride contents, blood pressure over 160 mm Hg occurred in only 3.4% of the adults /5/. When the morbidity of gall stones in two other Russian localities with various calcium, chloride and sulphate contents in the drinking water is compared, a considerably higher portion of the named diseases was discovered in those consumers who drank the water containing the calcium-chloride and calciumsulphate /6/.

As it is, exclusively geologically supplied substances appearing or lacking in water, can lead to diseases in humans. In 1901, for example, in Italy, near Naples, tooth enamel changes were observed, which appeared in 1916 in the Colorado area and in 1931 could be traced back to increased fluoride amounts in drinking water. Meanwhile, these irreversible tooth enamel changes were discovered in many states in the U.S., in addition to Canada, Mexico, Argentina, China, the East Indies, North Africa and Spain, especially when the drinking water of a population comes from vulcanic regions /7/.

In the USSR, the teeth of a group of 5,800 infants and 3,700 children were compared, whose drinking water for years contained a natural fluoride content of 3-4 mg/l F. A similar control group received 0.9-1.3 mg/l F. It was established that with water consumption with a high fluoride content, cavity prevention was clearly demonstrable in infants' baby teeth, but not in school children, while fluorosis-type tooth alterations were relatively rare in baby teeth, but were present in 60% of the school children /8/. In one province in China, where the drinking water contained 3-13 mg/l of fluoride, all the inhabitants of 17 years of age had tooth and joint damage. In a post-mortem of one inhabitant, the results were that the fluoride content of bones had increased twenty-fold, the weight of the bones thirty-fold and that the spine was completely fixed /9/. In contrast to these varying amounts of fluoride in drinking water on the basis of geological dif-

ferences, are the findings of the U.S. Public Dental Health Center /10/ which undertook an objective artificial fluoridation of water supply installations in schools. Fluoride amounts were used which were considerably higher than those usually added in the fluoridation of central water supply plants. Under the same geographical conditions, 3 schools received 2.3 mg/l to 4 mg/l of fluoride in the drinking water. The test period was 8 years. The decrease in cavities was between 22 and 34% in relation to the control schools with non-fluoridated water. Tooth fluorosis, to the degree which could be viewed as expected, did not appear, although, as previously mentioned, fluorosis on the basis of natural fluoride contents in drinking water had long been known in many states of the U.S.

In the transition from our natural environment to a civilized one, and under the influence of civilization, the first greatest problem of chemical pollution of ground water, combined with diseases thereby induced, was the nitrate problem. In epidemiological research, there are many considerable differences of opinion on the significance of the findings; because, while especially in the East European countries and in the near East, mostly sub-acute cases of methenoglobinemia were noted /11/, in western countries with centrally supplied drinking water, no drinking water-induced diseases were mentioned. Furthermore, the problem proved to be more complex than first thought. While Israel, by way of example, blamed

the introduction of sewage for ground water enrichment by way of absorption wells for the increase of nitrate in ground water and thereby causing sub-acute methenoglobinemia /12/, it is pointed out that on the American side /13/, the state of California has doubled the limit of nitrate in drinking water, because a clinical case of methenoglobinemia has never been observed. Complications in the evaluation arise, furthermore, due to the fact that a direct relation between drinking water-nitrate contents/methenoglobinemia obviously does not exist, but that the disease is induced by means of additional factors, namely, for example by a defective composition of intestinal flora present in an infant, bacteriologically imperfect water, a genetically-caused lack of methemoglobin reductase or a lack of Vitamin C. This could be an explanation for the lack of the disease in California, but for the presence of it in Alaska or in Czechoslovakia /14/. Due to the recently demonstrated possibility of the formation of carcinogenic nitrosamines /15/, the nitrate problem has again taken another completely different turn, which takes into consideration a mostly avoidable danger not for a small population group, but for large population groups.

The result of the above is that quality characteristics can appear, which are contingent upon the source of water. The preference of ground water as drinking water was a result of the discovery of infectious viruses and the development of drinking water epidemics from river water polluted by sewage. The physical-chemical and biological purification processes taking place in the ground for protection from epidemics,

are not sufficient to leave the chemical quality of the ground in a condition which excludes health hazards, i.e., that classical protection of ground water by means of protective zones against disease viruses is indeed effective, but is imperfect against chemical morbific agents, especially since the possible harmful substances can be manifold in addition to the already known poisons /16/.

Up to now, the described epidemiological research, in the meaning of the definition, refers to etiologically fixed, temporary and locally limited, frequently appearing diseases, but not to that which for us today has the character of a real national disease. Among modern national diseases are in the first place, rheumatism, diabetes, cancer, heart and vascular diseases. In connection with the effects of water contents, rheumatism and diabetes are factored out. The significance of water contents as causative factors in definite multifactor carcinogenesis, should therefore not be left out of consideration here, since special presentations are being held on potential carcinogenic substances, such as, for example, zinc, arsenic, nitrosamines, or polycyclic aromatic hydrocarbons within the framework of this event. Thus, as the last of the above-mentioned national diseases, heart and vascular diseases remain for epidemiological analysis.

As is well known, there is the possibility to determine environmental factors, which could have significance as to the origin of a disease, or come into question as a hypo-

thetical case, retrospectively or prospectively. With retrospective studies one starts with a group of persons who suffer from a certain disease and compares it with retrospect to the presumed cause with a healthy control group. With prospective research, a group is observed with regard to a definite, etiologically important environmental factor over a definite time period, and compared with a group which has been exposed considerably less or not at all. As a rule, primary causes of a disease and secondary dispositional factors complement each other, which can be evaluated by age, sex, race, profession, living habits, stress situations, nutrition, alchohol and nicotine abuse, pregnancy, among others. Doubtless, with heart and vascular diseases, secondary factors play a decisive role, particularly since there is no knowledge of a single specific etiological factor yet. However, for their development, certain postulates must be fulfilled in order to recognize a factor as a cause, i.e.,

1. The risk of disease increases with the duration factor and the intensity of the effect of the factor in question.

2. The field of the disease and the field of the factor in question must be congruent.

3. If the influence of the factor in question is eliminated, the number of diseases must decrease.

In addition, the question of a correlation between the hardness of drinking water and public health has been brought

up. Gärtner /17/ pointed out in 1902 that the hardest drinking water known to him, with a total hardness of 102 °dH and a carbonate hardness of 88 °dH was in the Thuringian city of Bürgel, and that it "had been consumed without harm for 100 years." Conversely, in the same time period, water which was too soft was shown to be detrimental to health /18/. Therefore, soft water was particularly rejected because it "aids tooth decay and also influences physical development, so that, for example, in men, military fitness, and in women breast-feeding declines." /19/ Already in 1913, a dissertation deals with the significance of lime salt in drinking water for human metabolism in reference to the use of softened drinking water /20/.

With the increasing number of heart and vascular diseases, epidemiological studies were suggested by way of retrospective analysis for the clarification of etiological factors to also include environmental factors in the research. In addition, there was also a consideration of drinking water. In 1957, Kobayashi /21/ provided the initiative for the suspicion that some kinds of vascular diseases could be related to the contents of drinking water. He established that the number of deaths from apoplexy was especially high in that area of Japan where the river water contained much sulphur, but few carbonates. It was followed by research by Schroeder /22/ who compared not the number of deaths from apoplexy, but from cardiovascular diseases in individual states of the U.S. from 1950 to 1960 and found a mortality maximum in South Carolina

and a mortality minimum in New Mexico. In searching for the cause of this difference, he hit upon the fact that there was a negative correlation between the number of deaths and water hardness. In the differentiation of the concept "cardiovascular diseases," he found a correlation between soft water and heart diseases caused by high blood pressure, between soft water and ischemic heart diseases and - admittedly not statistically as well defined - between soft water and vascular disturbances in the brain /23/. One year later, Morris and Crawford /24/ reported on the same correlation between soft water and a higher number of deaths from heart and vascular disturbances in England. Hypertension also showed a correlation, although not quite as clearly.

It should not go unmentioned here that the same negative correlation with bronchitis was found. In addition, they searched for correlations between water hardness and some 60 socio-economic parameters, among others, income, educational level or professional position, population density, smoking, traffic accidents and air pollution. In the statistical light of these parameters, the soft-water/bronchitis correlation collapsed, while the soft-water/heart-related death correlation remained valid. In contrast to Schroeder, who found the calcium, carbonate, magnesium and sulphur contents of drinking water likewise significant, Morris and Crawford only reported the calcium and carbonates in water as significant. Schroeder /25/ verified his 1950 findings in 1960; Crawford and colleagues /26/

their 1951 results in 1960. Both found the negative correlation water hardness/heart deaths, water hardness/hypertension, and water hardness/brain vessel disturbances substantiated. Masironi /27/ compared the mortality with the hardness of drinking water from four large American water supply systems. The residents of the Ohio and Columbia river areas had soft water and those in the Missouri and Colorado areas hard water. The findings were further complicated since he did not use calcium or carbonate contents as parameters, but the radioactivity of the water reservoir. Even so, he was able to establish that deaths from hypertension and cardiovascular disturbances decreased when the radioactivity increased. In the users of the soft water from the Ohio area, mortality from hypertension was 41% and from heart infarction 21% higher than the residents with the hard Colorado water.

Crawford and colleagues /28/ established that with an average increase in cardiovascular mortality of 12% during the last years, the rate in 5 cities with hard water was below this average with 8.5% and in 6 cities with soft water above this average with 20.2%. They also /29/ compared in London (hard water) and Glasgow (soft water) the mortality and the pathological-anatomical findings of the hearts of patients with heart infarction and traffic deaths. First, there was an almost doubled infarction mortality in Glasgow (soft water) and secondly, a considerably higher rate of heart changes in the traffic deaths. On the other hand,

there was a very small calcium and magnesium content in the cardiac vessels of those deaths in Glasgow, while ahteroma and strong stenosis was established in the arteries of the Londoners. It was concluded therefrom that soft water does not cause any arterioschlerotic heart damage, but that the heart infarctions arise from other changes.

It should be added that in Sweden, Biörck and colleagues /30/ also found a negative correlation between water hardness and ischemic heart diseases and brain vessel disturbances. In Holland, Bierstecker /31/ confirmed the findings. On the other hand, Bostrom and Wester /32/ in Sweden observed the correlation only in women. Lindemann and Assengo /33/ found no correlation between water hardness and heart diseases in Oklahoma. Mulcahy /34/ could find no correlation in Ireland, and in Czechoslovakia there was also no connection reported /35/. Anderson /36/ found a correlation between soft drinking water and sudden arterioschlerotic death, conditioned by arrhythmia in the first hours of the infarction caused by a low serum calcium level.

These results, obtained mostly on the grounds of retrospective epidemiological research, are in contrast to the pathological-anatomical findings of Correa and Strong /37/. They examined over 23,000 coronary vessels and aortas of patients, who had lived in 14 different countries of the world and related their findings to the water hardness of the supply area in question. The 14 different countries, for

example, the USA, Norway, South Africa, the Philippines, South America, the West Indies, etc., make also possible the inclusion of race differences in the numerical evaluation. Strong and Correa, in contrast to the above-described findings, could not establish any relevant connection between water hardness and vascular changes. By way of example, in New Orleans in whites and blacks there was a high mortality from coronary sclerosis, but the drinking water contained 91 mg/l $CaCO_3$. The residents of Bogota, Cali and San Jose drank water with a $CaCO_3$ content between 20 and 40 mg/l and had a very low mortality figure. The inhabitants of Jamaica drank water with a $CaCO_3$ content of 213 mg/l and showed no above-average mortality rate from heart and vascular diseases. In Durban, which had soft drinking water, the Bantus had a low and the Indians a very high mortality figure, although both drank the same water. Only the amounts recorded in Lima, Oslo and Santiago contained a proportionate soft-water/high mortality correlation from coronary diseases. Strong and Correa concluded therefrom that the correlation between water hardness and cardiovascular diseases is not a direct function of the chemical make-up of the water.

There remains, therefore, an unknown factor X, of which it is not known whether it acts as a protective function in hard water or a harmful function in soft water. Since soft water absorbs certain metals more easily than hard water, there was a logical attempt to search for this factor X in

the form of metallic ions present in water. Thus, Schroeder /38/ established an increase in the cadmium contents of the kidneys with increasing age, often accompanied by an increase in the zinc content and causative correlation with high blood pressure.

In ground research in Georgia, Shacklett and Sauer /39/ demonstrated that in coastal areas with a high cardiovascular mortality, there was a particularly large amount of zirkonium. Vitale and colleagues /40/ showed that magnesium promotes lipoid deposits in the aortic and cardiac valves. Sauer /41/ established that the drinking water in 9 out of 10 researched areas with high cardiovascular mortality contained hardly any magnesium. Strain /42/ attributes the protective effect of hard water to the vanadium content, and Wouter Voors /43/ was able to demonstrate that in hard water lithium present at the same time protects against infarction. D'Alsonzo and colleagues /44/ examined the sera of 20 new infarction patients and 20 control persons for nickel, molybdenum, boron, zinc, silver, lead, manganese, iron, magnesium, sicilicium, titanium and aluminum. Nineteen of the 20 infarction patients showed a very high nickel content, while such was the case in only 4 sera of the control group. This difference was thought significant.

For those engaged in epidemiological analysis, in data concerning water, there were not any detailed statements on the chemical proportions in drinking water. In part, hardness

values were used as average figures for a whole city in spite of varying supply areas. The factors necessary for the evaluation of water such as mixed water, static water, data such as total or carbonate hardness, separated data on calcium and magnesium content, data on the pH amount or on the presence of saturation pH, on the substance of water distribution systems or the nature of untreated water and the purification are in no case considered. It can be assumed that by including these drinking water parameters, there would be other more clearly defined or even no correlations. The above-mentioned factor X is certainly not primarily identical with the presence or lack of hardness formation in water, but could be in correlation with them, that trace elements such as cadmium or lithium in soft water are more solvent in soft water from underground or distribution systems.

Up to now, the described statistical research data referred to water whose various degrees of hardness were geologically implied. With the increase of appliances for treatment of drinking water in order to soften water in private dwellings, but also if there were to be a central softening in the German water works, the problem of the parameter X correlation between water hardness and heart infarction will necessarily move to the forefront.

Thus, Snanholtz /45/ in 1968, noted that according to the nature of the water softening, a large sodium content in the water can result. He sees a connection between this sodium

abundance in drinking water and cardiovascular diseases as a result of sodium-damaged kidneys.

When, in its time, central fluoridation of drinking water for cavity prophylaxis came under discussion, the following point of view was given as a counter argument: is it justified, with an average use of water of 200 l. per person per day to fluoridate 2 l. of drinking water, so that at the same time 198 liters of used water is achieved? Now the opposite question arises: it is indeed possible technically to soften the daily use of water, but is it justified that in the process 2 liters of perhaps not entirely harmless drinking water, healthwise, not be taken into account?

In view of the previous unclear and complex nature of the problem, extensive and detailed comparative research is necessary in order to achieve a uniform and relevant formation of opinion. This research must apply to drinking water contents as well as anamnestic and pathological findings in humans.

The purpose of this exposition was to show that in addition to real water-related diseases, which have specific and fixed causes, the possibility exists, that there could be a correlation between disease and one or more water-related or reported factors. In these cases, it is the rule not to give a simple correlation between cause and effect. The use of drinking water of a certain composition can represent a necessary precondition for the development of a certain diseases, but does not necessarily have to be the only cause.

To the age-old rule of Paracelsus, that the question of whether something is poison or not, depends only on the dose, a qualification must be considered; that it no longer depends on the dose, but also on the amount accumulated in the organism and, respectively, on the concentration in the most sensitive organ. According to statistical reports, it is not to be excluded that a critical situation can develop as a result thereby, that over a long period - even decades - the smallest harmful amounts can be absorbed or the smallest amounts of protective substances can be produced. The problems in the research of these effects arise from the to-be-calculated individual reaction of each person and from the proportions in drinking water, ignored up to now, which can be more clearly differentiated. Thus, an infarction is not viewed as to whether it occurred through stress, coffee or nicotine abuse, bad nutrition or from harmful environmental influences.

As long as there is the possible connection: the parameter "soft water" correlated factor X/heart infarction is unsolved, medical treatment and hygiene measures should be determined according to the motto "In dubio pro reo."

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